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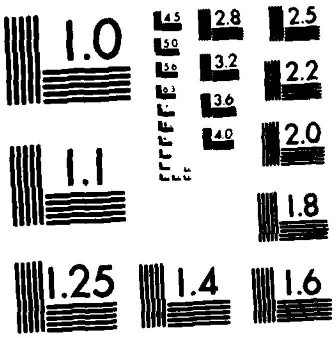

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VISUAL REPRESENTATIONS SUBSERVING TEXTURE PERCEPTION

(First annual report, April 30, 1983 - May 1, 1984)

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1. ABSTRACT

The ongoing research investigates the representations of visual texture and the processes that detect discontinuities and structure in visual texture. Psychophysical experiments have investigated the salience of bar orientation and the effect of groupings in texture segmentation. We are examining the role of elongated receptive field mechanisms in computing both local measures of orientation and their possible role in texture segmentation. We have found such mechanisms, however, to be less appropriate for determining one-dimensional groupings of (collinear) discrete items of texture. Combined psychophysical and computational studies have provided evidence for place tokens in groupings, and current work is directed towards understanding how these tokens may be defined in fine-scale texture detail. To support this work, a vision laboratory has been established based on a Symbolics 3600 Lisp Machine.

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The ongoing research investigates the representations of visual texture and the processes that detect discontinuities and structure in visual texture. Psychophysical experiments have investigated the salience of bar orientation and the effects of groupings in texture segmentation. We are examining the role of elongated receptive field mechanisms in computing both local measures of orientation and their possible role in texture segmentation. We have

found such mechanisms, however to be less appropriate for determining one-dimensional groupings of (collinear) discrete items of texture. Combined psychophysical and computational studies have provided evidence for place tokens in groupings, and current work is directed towards understanding how these tokens may be defined in fine-scale texture detail. To support this work, a vision laboratory has been established based on a Symbolics 3600 Lisp Machine.

2. OBJECTIVES

The ongoing research investigates the representations of visual texture and the processes that detect discontinuities and structure in visual texture. The research seeks to understand how the visual attributes of texture are computed by the human visual system. In general, our approach is concerned with two issues, one being how properties or attributes of texture are defined (such as the orientation of small blobs and bars) and secondly, how these properties are used by subsequent processes (such as those that detecting texture boundaries and detecting collinear or parallel arrangements among these elements). Psychophysical experiments are planned to probe both the processes that operate on texture, to find boundaries and so forth, and the processes that deliver the underlying visual representation of the texture. In parallel we are developing a computational basis for these processes that is consistent with the known neurophysiology.

3. RESEARCH STATUS

In our first year we have acquired most of the equipment in our computational vision laboratory, and begun several parallel experimental and computational studies.

3.1 Establishing the vision laboratory

The laboratory is centered on a Symbolics 3600 Lisp Machine, which has been installed the Psychology Department. Funding for the equipment was received in August 1983 and delivery of the Lisp Machine was made in October. The Lisp Machine was connected via Ethernet to the Department of Computer and Information Science VAXs and Lisp Machines in December, thereby providing access to file structures at the two sites.

Auxiliary items of equipment are a Tektronix 690SR color monitor and an NEC Spinwriter. Also, a grant application to Tektronix for a video hard copy device was approved; a 4634 valued at $7900 was donated for our research project.

The laboratory is still in its initial development, awaiting delivery of the Robotics Systems digital frame buffer and digital convolution systems. This equipment is based on very new technology and has involved development at Robotic Systems of a new interface based on the recently developed 3600 architecture. The delay in acquisition of our color frame buffer has prevented our use of the Lisp Machine for grey-level and color graphics. In the interim period we have concentrated on experiments that can be performed using the existing high resolution bit-map graphics on the 3600 console. We have just received the frame buffer and it is currently being installed concurrent with Symbolics' new Release 5.0. The convolution system is expected in June. When this equipment is also installed we will have facility for digital convolution and image processing similar to that at the MIT Artificial Intelligence laboratory.

3.2 Research

Previous research has demonstrated the importance of a small number of properties for texture perception, including orientation, brightness, and size. The current research is investigating in detail the means by which orientation is defined in texture, and the precise role orientation plays in texture discrimination, perceptual grouping of texture elements, and other processes in texture perception.

3.2.1 The salience of bar orientation

Two regions of texture composed of oriented elements will segregate on the basis of orientation differences. Our research has shown that not all geometrically equivalent changes in orientation are equally effective in producing texture segmentation. We have been developing a computational model which allows us to predict the effectiveness of orientation differences in producing texture segmentation. One model we currently explore is based on the assumption that an orientation is measured in terms of elongated receptive field structures, and that two regions of texture segment when receptive fields of common orientation and spatial extent in the two regions receive different excitations. The degree of segmentation is weakened by the degree to which texture elements in the two regions stimulate receptive fields of common orientation.

In one experiment, texture segmentation was examined in patterns consisting of discrete bars where two regions differ in the orientation of the constituent bars. The bars in one region were oriented 10° from the horizontal and those in the other region were either 20, 30, or 40°. Four conditions were examined — corresponding to two bar widths (approximately 1′ and 2.5′) and two bar lengths (approximately 3′ and 6′). When the orientation difference was 20 or 30°, increasing the width of the 6′-long bars increased the perceived texture segmentation. When the orientation difference was only 10°, increasing their width decreased the perceived texture segmentation. When, on the other hand, the bars were 3′ in length, the texture segmentation decreased with the wider bars. (Except, for the short bars a 40° difference was also examined, with the result being equal texture segmentation for the two widths.) From the point of view of stimulating the excitatory region of a elongated receptive field, the wide bars would be much more effective than the narrow; the visual system is approximately 28 times more sensitive to the wide than to the narrow. The orientation "difference signal" is apparently not only a function of the strength of stimulation of receptive fields of the specific orientation, but also of the number of receptive fields stimulated in common.

The smaller the angle difference and the shorter the bar, the more two elements will stimulate differently-oriented receptive fields similarly, and the less pronounced would be the perceived segmentation. One can see that the orientation difference between 10 and 20° narrow bars is the same as between 10 and 20° wide bars. This suggests that the geometric difference is not what matters, but rather some measure that confounds orientation and energy.

We are presently investigating more carefully how texture segmentation varies with bar length, width and intensity, and comparing the results to an emerging theory for the role of elongated receptive fields in the measurement of orientation differences in texture. While we are examining several computational models involving receptive field organizations, we do not expect them necessarily to correspond to the simple cells discovered by neurophysiologists. Other experiments (see below) are, in fact, implicating a higher-level encoding of the spatial properties of the texture.

3.2.2 The role of groupings in texture segmentation

Texture segmentation cannot be accounted for solely in terms of first order statistics of the image intensity distribution. In addition to processes of segregation, the perception of texture involve processes of aggregation. For instance, preattentive grouping of elements may give rise to different texture descriptions in two abutting regions. That is, differences in the resulting groupings can be shown to give rise to perceptually distinct texture regions. We have begun experiments to investigate how element orientation, size, and brightness affect grouping processes in texture.

One type of stimulus consisted of three regions, a horizontal central region flanked by regions above and below. Each pattern consisted of a given type of element (either vertical bars, squares or circles) of two different sizes. In the top and bottom regions, the pattern consisted of columns of either large- or small-sized elements, while in the middle region the large and small elements alternated. The middle region appeared more or less distinct from the flanking top and bottom regions.

Our experiments have shown that a scaling of the entire stimulus patterns reduces texture segmentation for non-oriented elements such as circles and squares, but that scaling leaves texture segmentation either unchanged or improved for oriented bars. A second series of experiments has shown that the texture segmentation is a U-shaped function of intensity. The segmentation is decreased when the intensity of the (non-oriented) elements is increased from approximately 1.5 to 6.4 foot-Lamberts. The results suggest that we are dealing with an interference effect. Increasing either the intensity or the overall size of the elements through scaling seems to cause them to interfere with the original groupings of the elements into columns. An overall increase in intensity seemingly increases the salience of the smaller elements, putting them into competition with those in the columnar groupings. Overall, this experimental series appears to be revealing two facts: that groupings can play a significant role in texture segmentation, and that in this role, oriented elements are functionally different from unoriented elements. These results are not easily accounted for by simple cell-like feature detectors responding directly to the columns of elements in the top and bottom regions of the patterns. Simple cell-like detectors would be expected to scale, that is, to maintain an approximately constant proportion of length to width. Consequently the expectation would be that scaling would yield the same texture segmentation. It is also not clear why an increase in overall brightness would decrease the texture segmentation.

3.2.3 Evidence for place tokens

Visual texture is composed of seemingly discrete items or elements, even when the underlying intensity distribution is continuous. One can localize and define the shape of blotches, bars, tiny blobs, and so forth in the image; when these items are elongated they are attributed an orientation. It is not yet clear whether the orientation measure that is attributed to discrete and visually distinct items in texture is also that which governs texture segmentation and other texture phenomena, or whether a more primitive measure of orientation is responsible (such as a Fourier-based or simple cell-like local measurement of the intensity distribution). Determining the answer to this problem is quite challenging; to do so requires developing specific models for the two alteratives.

Part of our research on this problem has involved finding evidence for texture groupings that cannot be easily accounted for in terms of Fourier- or simple cell-like receptive field schemes. To argue that a given texture effect is not accountable by Fourier-based means is an indirect argument for some (as yet unspecified) symbolic scheme, one which treats the individual elements as discrete items. Since it is not clear precisely what it means to treat items of texture as discrete symbolic markers for grouping purposes, it is still a rather difficult notion to test. Moreover, since there is no common understanding of how the alternative (Fourier-based) schemes are implemented in human vision, similar difficulties arise. Nonetheless, that is the state of affairs in this area.

Consider the simple grouping phenomenon in which a row of dots appears to cohere into a dotted line, a one-dimensional grouping. The two alternative hypotheses are *i)* that the dots are treated as place tokens, and *ii)* that they are not, but that the orientation of the dotted line emerges by some spatial blurring operation that detects the linear arrangement.

We have found several types of evidence that simple cell mechanisms are not the sole means for detecting linear organization in dot patterns. The conclusion we draw, therefore, is that for at least some one-dimensional grouping phenomena, the items that comprise the perceived organization must be treated as individuals, as place tokens. Several observations support this conclusion.

First, we examined dot patterns that present obvious geometric organization, but for which little information is carried by relatively low spatial frequencies. One way is to make patterns composed, not of simple dots, but of small items that present little power in the spatial frequencies on the order of 1/s, where s is the spacing between the items. A second line of evidence against the Fourier-based schemes involves dot patterns where the collinear dots are not relatively isolated, but rather, embedded in a roughly uniform and isotropic dot distribution. For these patterns, if a simple cell were presented with a row of dots in its excitatory region, there would be roughly equal energy presented in its inhibitory flanks, and consequently the linear organization among the dots would not be detected. An example of this sort of pattern is given by the Marroquin patterns. Further evidence is provided by the simple observation that we can see pairings between dots that are separated by approximately 1°, which is well beyond the largest sustained channel (8.8′) in the central fovea. Still more evidence against a Fourier-based approach is posed by rivalrous dot patterns in which two potential organizations could be imposed, one between dim dots, another between dim and bright dots. The simple-cell model would predict the pairings between dim and bright dots; the perceived organization, however, is between the similar, but dimmer, pairs of dots.

The various demonstrations together argue against the specific proposal that bar-like simple cells are wholly responsible for the detection of linear organization in dot patterns. The more fundamental argument, however, is against the sufficiency of local Fourier analysis for detecting collinearity among point-like features in an image. The alternative, as we see it, is that the dots are treated by the visual system as discrete items, and their collinearity noticed by geometric constructions among these discrete items. The basic issue is the localization of the items that constitute one-dimensional groupings. We have shown that it is not sufficient to employ techinques based on spatial blurring; instead it would appear that places are localized in a fine spatial resolution description of the intensity distribution.

3.2.4 The representation of fine texture detail

A series of computational experiments have been performed to examine the representation of texture detail. Our approach has been to first study the description of texture at the smallest available visual scale, for which there is the greatest likelihood that the preceeding stages of intensity processing are linear (larger scales may be mediated, in part, by the transient, or Y-cell, channels, which are known to be highly non-linear). For the smallest available scales, therefore, we take as given that the texture description must somehow build upon a difference-of-Gaussians convolved image. The currently-popular hypothesis is that zero-crossings (ZCs) in the convolved image serve to localize intensity changes. Part of our task has been to examine this hypothesis in the context of dense, fine-detail texture, for which virtually no attention has been paid.

In this regard, one problem has been to account for the detection of the orientation of very small bars and blobs at the limit of visual resolution. Consider the smallest proposed difference-of-Gaussians channel ($\omega = 1.3'$ central excitatory region). The convolution of a short line segment of length approximately equal to ω would result in a closed zero-crossing contour of width approximately ω and a fractionally longer length. Detection of the orientation of this small bar would require sensitivity to the elongation of the closed zero-crossing. A series of pilot experiments has investigated how accutely we measure the elongation of the convolved bars, with preliminary results suggesting that we are sensitive to bar orientation where the closed ZC has a length-to-width ratio of only 1.4 to 1 or less. The completion of these experiments awaits the installation of our digital convolver.

At any scale of convolution the position of a zero crossing tends to meander, reflecting smaller-scale intensity variations. The ZC locus at any given scale is subject to artifacts that cannot be resolved at that scale, such as failure to resolve discrete items having separations less than ω, termination effects (blooming of the ZCs at the ends of bars or lines), and displacement of ZCs caused by adjacent intensity changes within approximately 2ω. A question is how to localize an intensity change at the smallest scale in the face of these artifacts. We have found phenomena suggesting that, in the absence of "supporting evidence" provided by spatial coincidence in a smaller channel, we use the ZCs, or some similar basis representation, for shape interpretations.

These experiments consist of observation of a checkerboard in a grey surround. When the individual squares subtend approximately 3-4$'$ the squares are aggregated along diagonals, and the squares along the border are prominent. When the squares subtend approximately 2-3$'$ the interior is a fine diagonal mesh, with the border squares elongated. When they subtend only 1-2$'$ the interior is a uniform grey, the border squares appear more elongated, and the corner squares are more prominent. Finally, at the extreme of resolution, at approximately .6-.8′, the border squares are barely detectable while the corner squares are sharp pinpoints. These effects are all reflected in the patterns of ZCs in the correspondingly-scaled convolutions. Our interpretation is that the ZCs at the smallest available scale forms the basis for perceived shape of texture detail, despite the artifacts of the convolution. Also, since these artifacts persist under scrutiny, they suggest a representation of smooth contour in the hyperacuity range (radii of curvature less than 1′).

In a related study we have examined the ZCs in dense texture and observed that places that appear prominent — to act as place tokens for apparent one-dimensional organization in the texture — seem to have a rather lawful interpretation in terms of ZCs. While not necessarily corresponding to isolated closed ZCs, they appear to be places of high combined contrast (slope across the ZC) and curvature. The current research is investigating various neurophysiologically-plausible mechanisms for localizing very small features in texture on the basis of the difference-of-Gaussians convolved image. A reasonable starting point is to consider ZCs, but evidence from other studies of hyperacuity and stereopsis implicate local extrema as well.

4. PUBLICATIONS

Beck, J., Prazdny, K., and Ivry, R. 1984 The perception of transparency with achromatic colors. *Perception and Psychophysics*, in press.

Beck, J. and Halloren, T. 1984 Effect of spatial separation and retinal eccentricity on two-dot vernier acuity. *Vision Research*, submitted.

Beck, J. 1984 Facilitation and interference of texture segmentation by grouping processes. *Perception and Psychophysics*, in preparation.

Beck, J. and Stevens, K.A. 1984 Salience of bar orientation differences in texture segmentation. *Perception and Psychophysics*, in preparation.

Stevens, K.A. 1984 Collinear aggregation by symbolic constructions on tokens. *Biological Cybernetics*, in preparation.

Stevens, K.A. 1984 Artifacts in the perception of visual detail at the limit of resolution. *Nature*, in preparation.

Stevens, K.A. 1984 A defocussing effect in the perception of geometric organization. *Science*, in preparation

5. PROFESSIONAL PERSONNEL

Co-Principal Investigators: Jacob Beck and Kent A. Stevens.

Graduate students in the Department of Computer and Information Science: Allen Brookes, William Goodwin, Cathryn Stanford.

Graduate students in the Department of Psychology: Richard Ivry, Richard Wildes.

6. RESEARCH MEETINGS

J. Beck: Paper at Meeting of the Psychonomic Society, San Diego, November, 1983.

K.A. Stevens: Invited talk at Vision Review, Endicott House, MIT, January, 1984.

J. Beck and K.A. Stevens: Participants at Workshop on Visual Organization, Fairchild

Camera, Palo Alto, February, 1984.

K.A. Stevens: Invited talk, Department of Computer Science, UBC, Vancouver, April, 1984.

J. Beck and K.A. Stevens: Participants, AFOSR Review, Sarasota, May, 1984.